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Power steering system for automotive vehicles

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FIG. 1

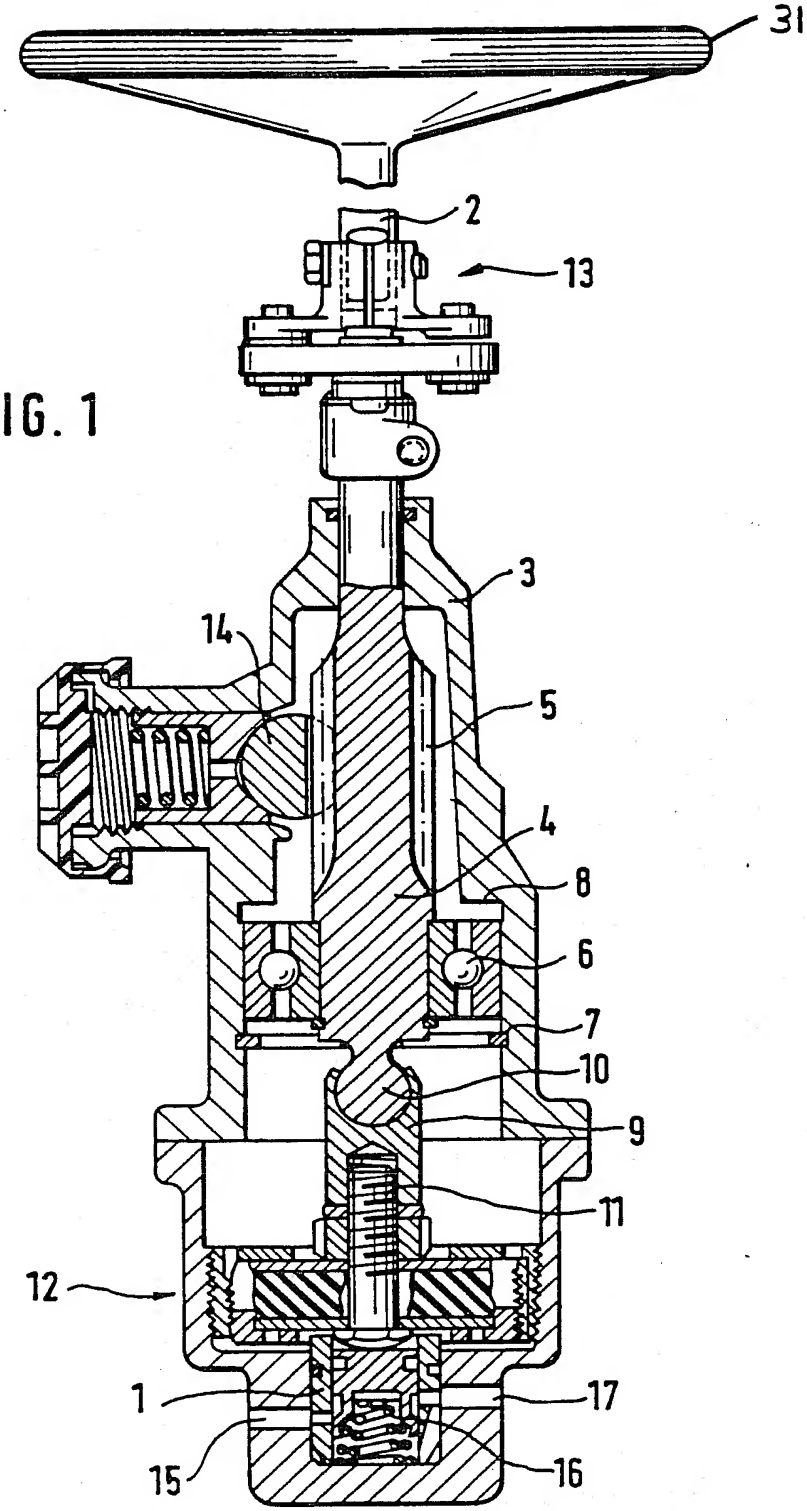
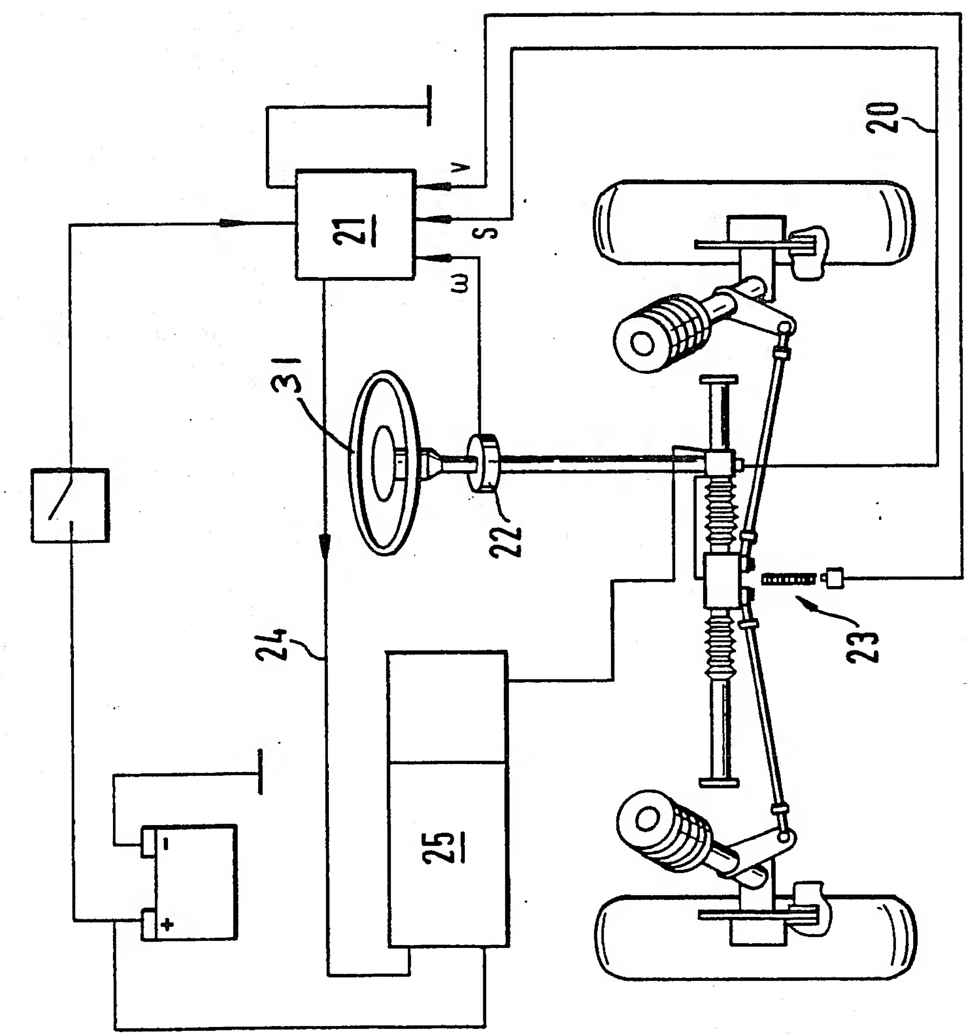


FIG. 2



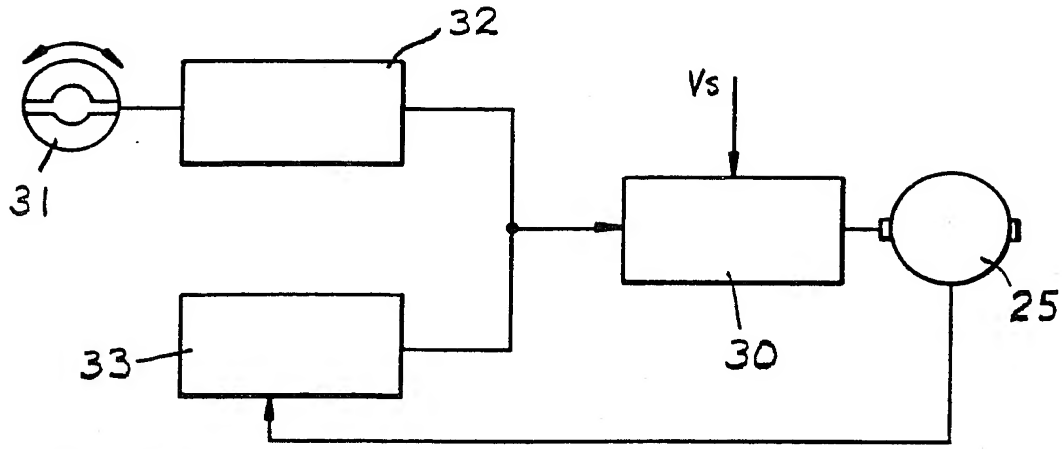


FIG. 3

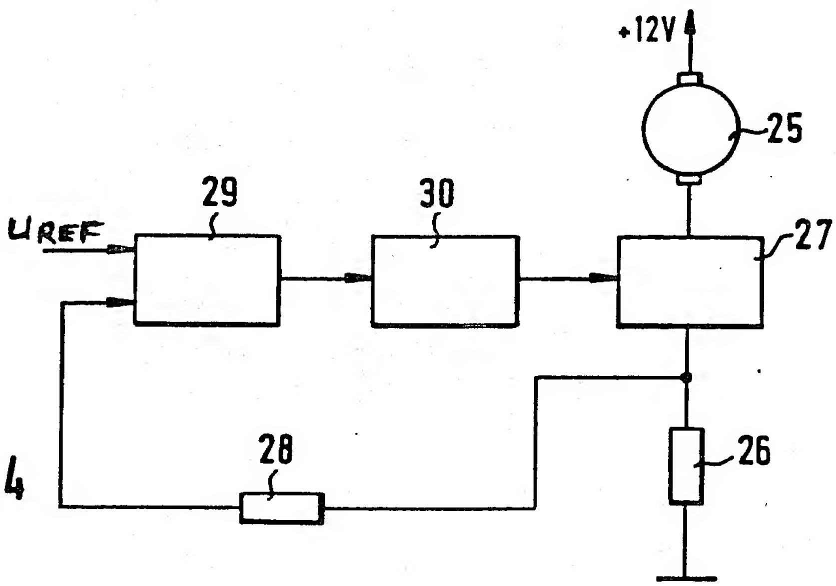


FIG. 4

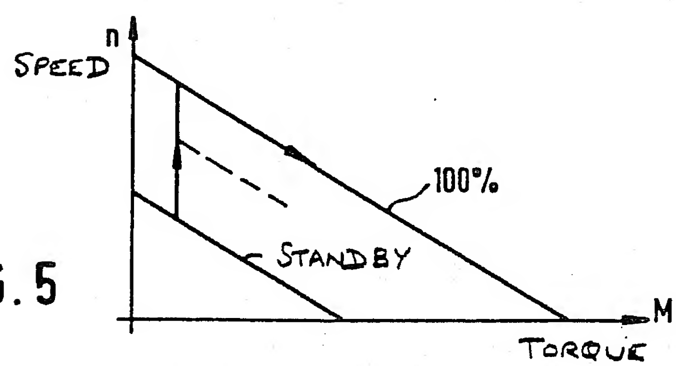


FIG. 5

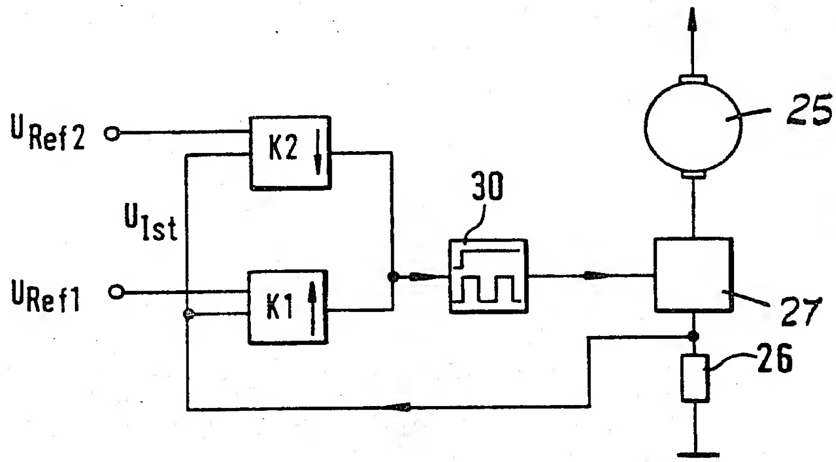


FIG. 6

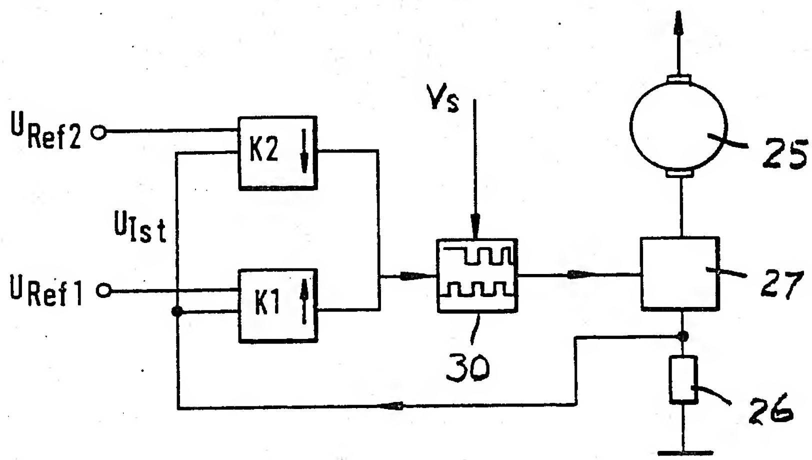


FIG. 7

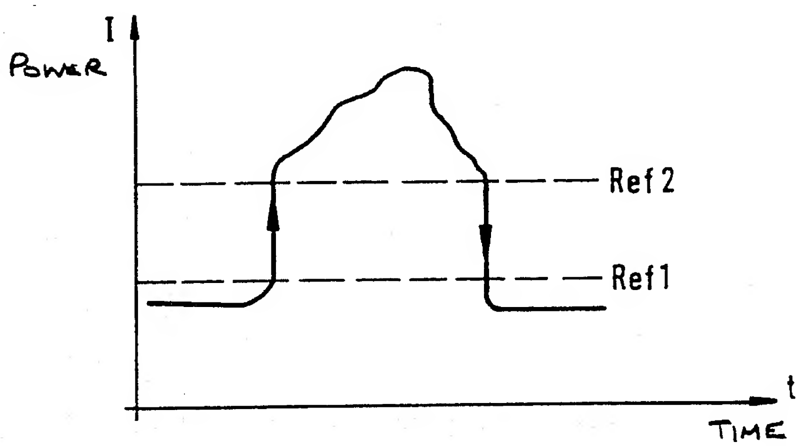


FIG. 8

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POWER STEERING SYSTEM FOR AUTOMOTIVE VEHICLES

The present invention is concerned with a power steering system for use with automotive vehicles.

More specifically the present invention is concerned with a power steering system comprising hydraulic pump means arranged to be actuated by an electromotor and connectable by a control valve and through hydraulic conduit means to at least one working chamber of hydraulic cylinder means coupled to a mechanical steering mechanism to support vehicle steering power, the power supplied to the electromotor during operation of the system being controlled by signals including a signal dependant upon the vehicle speed.

A steering system of the afore-mentioned kind is taught by published West German Patent Specification DE-OS 3100067 wherein electric power is supplied to the electromotor in response to speed. However, this will apply only when the steering mechanism is actuated. Although a conventional power steering system as compared with a power steering system wherein a hydraulic pump is permanently operated, involves an energy saving advantage, it will not be capable in the event of a sudden demand to quickly provide its full servo-power.

It is, therefore an object of the present invention to provide a power steering system which is of the above-described kind for use with automotive vehicles and which is characterised by low energy requirements, low electromotor

heating and an extremely short response time while and which at the same time is of simple structural design.

According to one aspect of the present invention there is provided a power steering system for automotive vehicles comprising hydraulic pump means arranged to be actuated by an electromotor and connectable by a control valve and through hydraulic conduit means to at least one working chamber of hydraulic cylinder means coupled to a mechanical steering mechanism to support vehicle steering power, the power supplied to the electromotor during operation of the system being controlled by signals including a signal dependant upon the vehicle speed, in which motor control means is effective for disconnecting the electric power supply to the electromotor above a first vehicle speed threshold and for energising the electromotor at reduced power below the first vehicle speed threshold, and in which the motor control means provides full electric power to the electromotor when the vehicle speed is below a second vehicle speed threshold lower than the first vehicle speed threshold and when the hydraulic cylinder means is activated, and in which the excitation of the electromotor is through a pulse-pause excitation arrangement in which the duration factor and/or the pulse frequency are variable in dependence upon the vehicle speed, and in which the hydraulic cylinder means is activated only after a steering torque threshold has been exceeded.

According to the system provided by the invention, the electromotor is switched off at high speeds, as is customary, for example, outside built-up areas.

In the speed range usually prevailing in urban traffic, the motor driven pump is operated in the so-called "stand-by" mode, so that, on the one hand, electrical energy will be saved and on the other hand, the hydraulic fluid is not excessively heated which has a favourable effect on the life of the parts concerned and on the general degree of efficiency of the system. Within the speed range outside about 20 km/h, the electromotor is also operated in the

"stand-by" mode; however, in the event of suddenly occurring high hydraulic power requirements, such requirements can be satisfied after an extremely short response time since the pump is already rotating and within a very short period of time will be able to generate its full power.

According to the invention, the hydraulic support to mechanical steering will be activated only after a predetermined steering torque threshold has been exceeded, thereby causing the electromotor to run up only in the presence of a minimum support requirement. This will again improve the energy-saving effect and will also minimise the noise development.

By way of example the present invention will now be described with reference to the accompanying drawings wherein:-

Figure 1 shows a steering mechanism of a power steering system according to the invention comprising a control valve coupled to the steering shaft through a captivated spring element;

Figure 2 shows an energising circuit for the electromotor of a hydraulic pump of the system;

Figure 3 illustrates a different motor energising circuit to that shown in Figure 2;

Figures 4,6 and 7 show an energising circuit for the electromotor of the power steering system;

Figure 5 shows a motor speed vs. torque diagram of d.c. electromotor of the power steering system, and;

Figure 8 shows a power vs. time diagram during a steering operation of the system.

Referring to Figure 1, this shows a steering mechanism wherein the relative movement between a steering shaft 2 and a shaft housing 3 can be used to operate a control slide 1 of a control valve. For this purpose, the housing 3 will be rigidly connected to the car body and the steering gear is configured as a rack-and-pinion provided with angular teeth. Section 4 of the steering shaft 2 carrying the driving pinion 5 is axially displaceable within the housing 3 by arranging that the outer ring of a ball bearing 6 fixed in the axial direction to the steering shaft is displaceably guided by a cylindrical sliding face between stops 7 and 8.

Section 4 of the steering shaft 2 is pivotally connected at one end to a connecting member 9 by means of a spherical end 10 of section 4 which is received by an end socket of the member 9. Screwed into the connecting member 9 is a screw 11 in abutment with the control slide 1 of the control valve and in communication with housing 3 in resiliently preloaded manner through the captivated spring element 12. To balance the axial stroke of section 4 of the steering shaft, the shaft is in communication with the steering wheel through an equilibrium means.

As the steering wheel is turned by the driver in one direction, the rotating movement of the driving pinion 5 of the rack-and-pinion is converted into an axial movement of rack 14. Due to the angular teeth of the rack-and-pinion, depending on the direction of rotation of the steering wheel, an axial force component acting on section 4 of the shaft 2 will become effective resulting in an axial displacement of that section 4 until the outer ring of the ball bearing 6 is in abutment either with stop 7 or with stop 8. In this way, pressure is applied to the control slide 1 in response to the steering direction. Control slide 1, in known manner, regulates the application of pressure to a working cylinder (not shown) comprising a differential piston and coupled to the mechanical steering

mechanism. The control slide 1 of the control valve regulates the communication between a pump connection 15, the chamber of the working cylinder having the larger pressure application surface - chamber connection 16 - and the non-pressurised - container - container connection 17.

Figure 2 schematically shows an energising circuit for the electromotor of the pump. The steering shaft 2 leads to a steering gear having a hydraulic cylinder coupled thereto and an integrated control valve generally of the construction shown in Figure 1. Provided on the control valve or on the driving pinion is a direction sensor a signal output from which is supplied to an electronic control means 21 over a connection 20. Moreover, signals from a steering speed- and/or steering torque sensor 22 and from a vehicle speed sensor 23 are also applied as input signals to the electronic control means 21, the latter sensor being formed by an electronic speedometer or by wheel sensors of an anti-locking brake system if provided. The electronic control means 21 can be connected to the car battery through the ignition lock and is connected with the electromotor of the motor pump assembly 25.

The electronic control means 21 actuates the electromotor in response to the speed, the steering torque and/or the steering speed in a manner continuously variable or, as in the case of a preferred embodiment of the invention, discretely in response to predetermined vehicle speed thresholds.

Once the vehicle speed sensor 23 indicates a vehicle speed of over 65 km/h, the power supply to the electromotor is interrupted. Since in the majority of cases at such vehicle speeds the steering torque will be so low that the pre-loaded control slide valve does not activate the hydraulic support, it will also be possible for the switch-off signal to be generated by the previously mentioned way sensor on the control slide of the control valve or on the driving pinion. This would involve the additional advantage that when the vehicle is negotiating long drawn out highway

bends having comparatively low radii the hydraulic support can be activated at speeds of more than 65 km/h.

In the vehicle speed range of between 20 and 65 km/h, the motor/pump re-switches to the so-called "stand-by"

mode. The motor will increase its performance however, if, in that speed range, the performance of the slow-running pump is not sufficient, which will also be detected by the way sensor or the steering speed sensor. If, for example, the driver turns the steering wheel heavily in this speed range, the pump electromotor will accordingly increase its speed to make available from the pump a sufficiently large hydraulic fluid volume. If in that speed range, the performance of the slow-running pump is adequate, the motor will remain in the "stand-by" mode.

The electromotor, at a speed below 20 km/h, will maintain the "stand-by" mode until a steering operation is initiated. Once the sensors detect a steering movement, the electronic control means 21 will immediately switch the motor to the maximum performance.

The motor-pump speed/torque diagram as shown in Figure 5, illustrates the run-up of the electromotor from the "stand-by" mode to its full performance while operating the steering mechanism within a speed range under 20 km/h. Once, in the speed range of between 20 km/h and 65 km/h, more hydraulic energy is required than delivered by the pump in the "stand-by" mode, it will also be run up from the "stand-by" mode, though not to the full performance but rather, as shown in broken lines, to a value of between "stand-by" and 100%.

Figure 3 shows schematically the controlled operation of the motor in response to the speed of the vehicle, to the steering speed and to the power take-up of the electromotor. The steering speed will be sensed by a steering speed sensor 32 coupled to the steering wheel 31 and the vehicle speed will be indicated to the control device 30 by a signal Vs which is proportional to the vehicle speed. Motor current is sensed by the current sensor 33. As the pump load will increase when applying pressure to the working cylinder the power take-up of the motor will also rise. Hence, the power take-up is also indicative of the steering torque. The current sensor 33 can, therefore, take over the function of

the way sensor on the control slide of the control valve or on the driving pinion, as shown in Figure 2, thereby simplifying the design of the general power steering system, as a current sensor can be readily integrated into the electronic control unit, whereas a way sensor, in addition to the assembly thereof, also requires an additional electronic connection between the mechanical hydraulic part and the electronic unit.

The control of the energisation of the electromotor is achieved according to the same pattern as in the design of Figure 2.

A reduction in the excitation of the electromotor, through a pulse-pause energisation of an appropriate duration factor or ratio, can be realised in a particularly low-loss manner by employment of a so-called power-MOSFET switch forming an electronic circuit. An electronic circuit of that type is schematically shown in Figure 4. The Power MOSFET 27 and a power sensing resistor 26 are series-connected in the current supply circuit of the motor pump unit 25. The voltage at the power sensing resistor 26 which is in proportion to the motor current, is supplied through a filter 28 to a comparator 29 for comparing the input voltage thereto to a reference voltage. The Power MOSFET switch 27, in response to a comparator output signal received through a control device 30 is switched on/off in pulsating manner or is permanently in the switched-on condition. If the voltage at the current sensing resistor 26 is below the reference voltage, the motor 25 is operated in a pulsed manner but once that voltage exceeds the reference voltage, the motor is permanently energised. To ensure a safe operation of the comparator 29, the comparator includes a hysteresis.

According to Figure 6, a voltage in proportion to the motor current and tapped from resistor 26 is applied to two comparators K1 and K2. The comparator K1 re-switches the pump motor from the pulse-pause excitation (stand-by) to permanent excitation once the actual input voltage to the

comparator exceeds the reference voltage U_{Ref1} associated with comparator K1.

If, after a steering operation, the input voltage to the comparators becomes lower than the reference voltage U_{Ref2} associated with comparator K2, the pump motor operation is switched back to the "stand-by" mode. The mode of operation of the two comparators, K1 and K2 is directionally dependant as otherwise there would be an undefined state between the two voltage thresholds.

In this respect, Figure 8 shows a power-versus-time diagram for a steering operation. Upon commencement of a steering action, the required steering torque will be raised, thereby causing the motor current to rise. Once a predetermined motor current value is reached, a first input or ACTUAL voltage at the current sensing resistor 26 exceeds the first reference voltage U_{Ref1} so that the motor is, therefore, excited to provide higher performance. If, after termination of the steering operation, the motor torque drops, the input or ACTUAL voltage tapped from the current sensing resistor 26, will be less than the second reference voltage U_{Ref2}. The electromotor will accordingly only run on stand-by performance. The control device 30 in Figure 6, shows a diagram of the pulse-pause excitation of the motor provided in the "stand-by" mode. The permanent excitation is shown diagrammatically above.

The circuit configuration according to Figure 7 is distinguished from the foregoing embodiments in that a variable or step-switched pulse-pause relationship can be additionally provided through the vehicle speed control. Hence, from the pump motor standstill to the permanent excitation, any desired characteristic can be adjusted.

CLAIMS

1. A power steering system for automotive vehicles comprising hydraulic pump means arranged to be actuated by an electromotor and connectable by a control valve and through hydraulic conduit means to at least one working chamber of hydraulic cylinder means coupled to a mechanical steering mechanism to support vehicle steering power, the power supplied to the electromotor during operation of the system being controlled by signals including a signal dependant upon the vehicle speed, in which motor control means is effective for disconnecting the electric power supply to the electromotor above a first vehicle speed threshold and for energising the electromotor at reduced power below the first vehicle speed threshold, and in which the motor control means provides full electric power to the electromotor when the vehicle speed is below a second vehicle speed threshold lower than the first vehicle speed threshold and when the hydraulic cylinder means is activated, and in which the excitation of the electromotor is through a pulse-pause excitation arrangement in which the duration factor and/or the pulse frequency are variable in dependence upon the vehicle speed and in which the hydraulic support means is activated only after a steering torque threshold has been exceeded.

2. A power steering system according to claim 1, characterised in that a Power-MOSFET and a current sensing resistor for pulse-pause excitation are provided in the electric power motor supply circuit.

3. A power steering system according to claim 1 or claim 2, characterised in that a displacement of a resiliently pre-loaded component disposed in a manner displaceable relative to the vehicle body and caused by the steering power serves for the mechanical steering actuation of the control valve.

4. A power steering system according to claim 3, characterised in that a captivated spring element is provided for the resilient pre-loading.

5. A power steering system according to any one of the preceding claims, characterised in that the first vehicle speed threshold is at about 65 km/h while the second vehicle speed threshold is at about 20 km/h.

6. A power steering system according to any one of the preceding claims, characterised in that the electric power supplied to the electromotor is in dependence upon one or more of the following variables:

a) steering speed and/or steering acceleration;

b) steering torque;

c) control valve motion or motion of a component of the mechanical steering means displaceable in response to the steering power.

7. A power steering system according to any one of the preceding claims, characterised in that the speed-responsive change in the power supplied to the electromotor at the reduced power is continuous.

8. A power steering system according to any one of the preceding claims, characterised in that the speed-responsive change in the power supplied to the electromotor is by a discrete change in power in response to marked vehicle speeds.

9. A power steering system substantially as hereinbefore described with reference to the accompanying drawings.